1657

Chemical Composition of Potatoes. II.

Relationship of Organic Acid Concentrations to Specific Gravity and Storage Time

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SUMMARY

Maine Katahdin potatoes were analyzed monthly during 8 months at 38°F followed by one month at 45°F and one month at 50°F. Glutamic, aspartic, pyroglutamic, malic, citric, oxalic, and phosphoric acids were determined. Potatoes of high specific gravity contained more citric acid and less pyroglutamic, malic, and phosphoric acids than did tubers of low specific gravity. Changes during storage were considerable relative to the amounts of acid present; most of the acids showed either a maximum or a minimum concentration after one or two months. Higher storage temperatures caused no significant change in the acid content of the tubers, but the resulting sprouts showed a markedly different pattern of acid concentrations.

THE AVAILABILITY of potatoes as a fresh, and to a lesser extent as a processed, vegetable depends on the efficiency of storage methods in preserving palatability and nutritive value and in regulating changes in composition. Studies of compositional changes in potatoes of various specific-gravity levels during storage may provide an insight into such changes and the problems resulting when processing industries use stored potatoes. Investigations of changes during storage have been concerned mainly with carbohydrates and total solids (Schwimmer *et al.*, 1954; Treadway *et al.*, 1949) and with nitrogenous fractions (Cotrufo and Levitt, 1958; Stuart and Appleman, 1935), but very little with organic acids, in spite of the central role that these compounds play in metabolism (Burris, 1953; Thimann and Bonner, 1950). Because of its nutritional importance, ascorbic acid has been studied somewhat extensively, e.g., Leichsenring *et al.* (1957) and Yamaguchi *et al.* (1960). Thunberg (1945) determined the citric acid content of several varieties of potatoes over storage periods up to 6 months. Minina (1953) investigated the concentrations of both citric and malic acids during seven months. The relative neglect of this field of investigation may be due to the inconvenience of determining each acid by a different method of analysis. The authors (Schwartz *et al.*, 1961), however, have adapted ion-exchange methods so that a single chromatographic run can determine glutamic, aspartic, pyroglutamic, malic, citric, oxalic, and phosphoric acids. In the present work these acids were determined monthly in three specific-gravity fractions of potatoes stored ten months.

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MATERIALS AND METHODS

Maine Katahdin potatoes were stored at 38°F beginning September 25, 1959. Each month a sample was removed and divided into six specific-gravity fractions with salt brines. Two samples each, of the highest, intermediate, and lowest specific-gravity fractions, were selected, peeled, and extracted with 70% ethanol. The samples and extracts used were the same in this and the earlier study (Talley *et al.*, 1961). The earlier paper gives further details on storage, sampling, and extraction methods; it also gives data on weight loss during storage, solids content, and specific gravity of the samples.

To induce sprouting after the initial eight-month storage period, a sample was stored one month at 45°F and then one month at 50°F.

Extracts were analyzed for acids by the above-mentioned method of ion-exchange chromatography (Schwartz *et al.*, 1961; Schwartz, 1960).

RESULTS AND DISCUSSION

Table 1 lists the results. To test the precision of the method, up to four replicate analyses were made on some of the samples. To test the sampling procedure, both samples of a particular specific-gravity fraction were analyzed in some cases. Table 2, which lists the Standard Deviations obtained, indicates that the precision of sampling was adequate when compared to the precision of repeating analyses of a single sample.

The results in Table 1 are not corrected for loss of weight during storage, which was about 0.7% per month. Since Talley *et al.* (1961), Treadway *et al.* (1949), and Schwimmer *et al.* (1954) have reported that the ratio of weights of solid loss to moisture loss remains nearly constant, the relation between acid content and specific gravity should not be affected by loss of moisture. Table 1 shows that, in general, the concentrations of all the acids except citric (calculated on a moisture-free basis) vary inversely as the specific gravity. With citric acid this inverse relationship occurs only in the last half of the storage period. These results confirm what would be expected from Metzger's finding (1956), that starch content increases more sharply than non-starch content as specific gravity increases. When calculated on a fresh-weight basis, the results show no definite relationship between the concentrations of glutamic, aspartic, and

Table 1. Relationship of acid content to specific gravity and storage time (moisture-free basis).

Storage time (months)	Glutamic[a]			Aspartic[a]			Pyroglutamic[a]			Malic[a]			Citric[a]			Phosphoric[a]			Oxalic[a]			Unidentified[b]		
	H[c]	I[c]	L[c]	H	I	L	H	I	L	H	I	L	H	I	L	H	I	L	H	I	L	H	I	L
0	....[d]	.32	.30	....[d]	.15	.23	.80	.66	1.22	.47	.54	.38	2.07	2.22	2.02	.19	.25	.27	.09	.10	.14	7.2	7.2	7.8
1	.32	.36	.47	.25	.16	.18	.37	.45	.74	.62	.42	.89	2.13	1.79	2.06	.24	.25	.38	.12	.12	.18	8.1	7.4	9.3
2	.49	.49	.56	.63	.27	.41	.44	.61	.82	.38	.76	.84	1.93	2.16	1.59	.35	.33	.37	.17	.18	.17	8.3	9.3	8.6
3	.36	.44	.41	.39	.41	.51	.22	.26	.36	.44	.52	.71	1.91	1.97	2.15	.25	.29	.42	.13	.16	15	8.5	8.6	9.8
4	.41	.41	.52	.37	.26	.37	.72	.28	.31	.40	.44	.54	1.94	1.69	2.25	.35	.40	.48	.13	.14	.08	8.3	7.2	....
5	.41	.39	.32	.27	.38	.45	.20	.24	.31	.47	.42	.59	2.01	1.93	2.15	.25	.26	.27	.12	.12	.13	8.7	8.1	8.6
6	.37	.40	.49	.33	.40	.37	.24	.31	.43	.35	.43	.52	2.12	2.15	2.22	.26	.30	.39	.12	.14	.17	8.2	9.1	9.8
7	.35	.35	.38	.29	.34	.43	.18	.21	.30	.32	.33	.45	2.00	2.08	2.19	.21	.23	.32	.07	.12	.14	10.3	9.0	8.9
8	.38	.43	.48	.31	.35	.42	.15	.20	.21	.35	.35	.41	2.19	2.38	2.37	.25	.25	.31	.14	.15	.15	9.2	8.7	8.2
9	.39	.42	.51	.39	.40	.47	.29	.34	.54	.33	.37	.44	2.22	2.25	2.57	.25	.29	.38	.14	.16	.18	9.0	9.2	10.1
10	.36	.40	.46	.38	.41	.50	.23	.26	.21	.37	.37	.43	2.36	2.34	2.24	.23	.30	.38	.14	.15	.20	9.0	9.1	9.9
10[e]		.24			.15			.08			.13			.61			.93			.30			9.6	

[a] Per cent weight. [b] Milliequivalents %. [c] H, I, and L respectively stand for fractions of high, intermediate, and low specific gravity. [d] No acid peak appeared. [e] Sprouts.

oxalic acids and the specific gravity of the potatoes. However, an inverse relationship between specific gravity and acid concentration is shown for pyroglutamic, malic, and phosphoric acids and a strong direct relationship for citric acid and the unidentified acid. Apparently, for a given variety and crop, high-solids potatoes are especially high both in starch and in citric acid, but lower in malic, phosphoric, and pyroglutamic acids. Pyroglutamic acid is probably not present in the fresh potato to the extent calculated, but is derived at least partly from glutamine during extraction or analysis.

Changes in acid content with storage time are shown in Figs. 1 and 2. Changes in the individual fractions followed the same general trends. Although the changes are not great on an absolute basis, they are considerable in relation to the amounts of acid present. It is notable that five of the eight acids determined—glutamic, aspartic, malic, citric, and oxalic acids—show either a maximum or a minimum concentration after one or two months. In addition, pyroglutamic acid, which decreases throughout, shows its sharpest decrease in the first two to three months. The over-all picture is one of an early period of rapid change in acid content, followed by a longer period during which some of the changes are slowly reversed. The results of Minina's study (1953) of changes in citric and malic acid content were similar in that they included an initial decrease in citric acid content followed by an increase, a decrease in malic acid toward the end of the period, and a preponderance of citric over malic acid at all stages. The increase in citric acid between the second and eighth months of

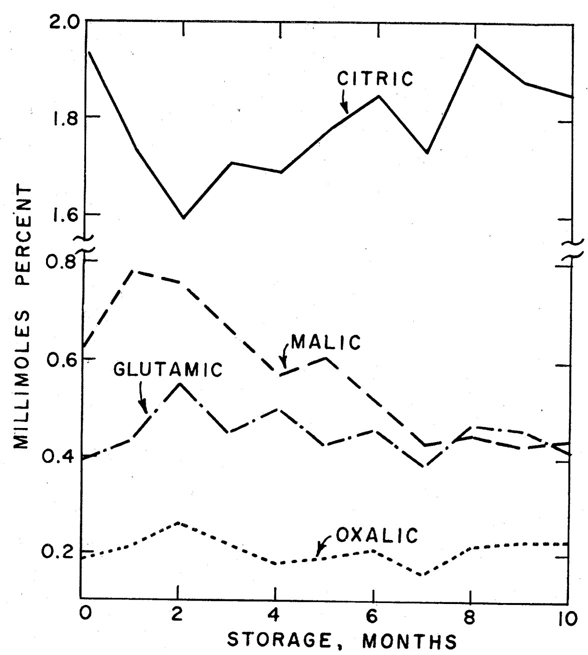

Fig. 1. Change in acid content with storage time (fresh-weight basis). Eight months at 38°F followed by one month at 45°F and one month at 50°F. Averages of three specific-gravity fractions corrected for loss of weight during storage.

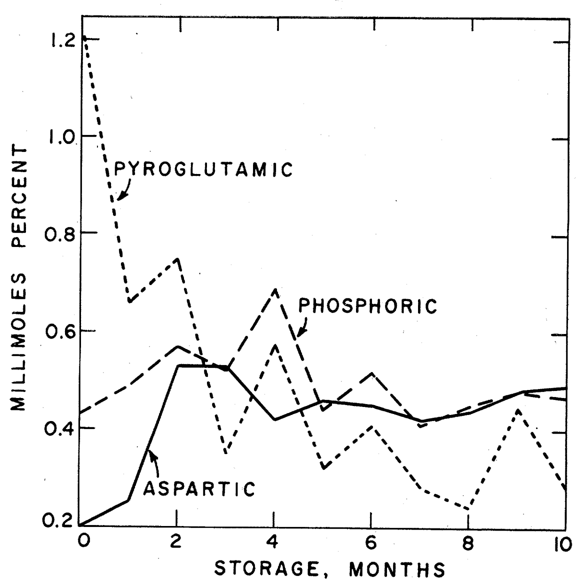

Fig. 2. Change in acid content with storage time (fresh-weight basis). See caption for Fig. 1.

Table 2. Precision of replication and sampling.

Acid	Replicate analyses		Replicate samples	
	Standard deviation	Degrees of freedom	Standard deviation	Degrees of freedom
Glutamic	.04	11	.02	7
Aspartic	.10	10	.05	7
Pyroglutamic	.06	11	.05	7
Malic	.05	11	.01	7
Citric	.06	11	.04	7
Phosphoric	.02	11	.03	7
Oxalic	.02	11	.01	5
Unidentified	.47	11	.26	6

storage (Fig. 1) is equal to the initial decrease, and to the decrease in malic acid occurring at the same time. This shows a possible conversion of malic to citric acid; such conversions have been reported (Krotkov and Barker, 1948; Pucher and Vickery, 1949).

The final two months of storage (higher temperatures) produced no significant changes in acid content of the tubers. However, the resulting sprouts had a strikingly different pattern of acid concentrations. Most of the acids were present in smaller amounts, but the concentrations of phosphoric and oxalic acids were greatly increased.

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